# EnVis and Hector — Tools for Ocean Model Visualization

Robert Moorhead and Sam Russ
Engineering Research Center
Mississippi State University
Miss. State, MS 39759
phone: (601) 325–8278   fax: (601) 325–7692   email: {rjm, russ}@erc.msstate.edu
Award #: N00014–97–1–0116

## LONG–TERM GOALS

The long–term goal is to allow ocean modelers to efficiently and rapidly visualize the output of their ocean models by effectively exploiting large scale computing environments. This necessitates a distributed, parallel, concurrent visualization system. The modeler should be able to seamlessly view and explore an evolving ocean model in an immersive virtual environment containing boundary conditions and context (topography, atmospheric model/data, man–made objects, etc.).

## OBJECTIVES

Traditional approaches to environmental visualization can usually be placed in two distinct categories: simple–but–functional and complex–but–powerful. Environmental scientists often write their own simple–but–functional utilities to provide rudimentary visualization of their data. These tools are usually good enough for most cases, but for cases that require further examination, more complex tools are needed. The problem is that most existing software falls in these extreme categories. The learning curve for the complex software makes it undesirable to the scientist. The situation is further complicated by the myriad formats that the data is natively stored in by each scientist and the need to derive quantities not explicitly stored in the native format.

The objective of the EnVis project is to provide a suite of related applications that span the full range of needs of the environmental scientist from the simple–but–functional to the complex–but–powerful. Criteria for the suite are as follows:

1. Applications should be closely related so that the learning curve can be overcome incrementally rather than all at once.

2. Tools should use an abstract data object that can be linked dynamically so that native format (and derived type calculation) is specified at run–time.

3. The number of applications and the functionality of existing applications should grow as the scientists discover new types of visualization necessary to explore and understand their data better.

There are also some software engineering objectives that are critical as well. The software developed for the EnVis project should be reusable. A successful scheme for the software reuse reduces the turnaround time for adding new features for the scientist's changing interests and needs. It also provides a foundation for greater access to the software contributions of all group members. In discussions with personnel at NRL/SSC (Pat Hogan, Alan Wallcraft, Richard Allard, and Peter Flynn), they indicated they would like a simple–but–functional tool to allow them to make a movie every night. Of all those movies they postulated they would examine 5 per year in more depth with an interactive toolset. They thought they would be interested in seeing one data set a year in an immersive virtual environment. Thus, we are focusing on the first two areas initially.

## Report Documentation Page

*Form Approved*
*OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

| 1. REPORT DATE **30 SEP 1997** | 2. REPORT TYPE | 3. DATES COVERED **00-00-1997 to 00-00-1997** |
|---|---|---|

| 4. TITLE AND SUBTITLE **EnVis and Hector - Tools for Ocean Model Visualization** | 5a. CONTRACT NUMBER |
|---|---|
| | 5b. GRANT NUMBER |
| | 5c. PROGRAM ELEMENT NUMBER |
| 6. AUTHOR(S) | 5d. PROJECT NUMBER |
| | 5e. TASK NUMBER |
| | 5f. WORK UNIT NUMBER |

| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Mississippi State University,Engineering Research Center,Mississippi State,MS,39759** | 8. PERFORMING ORGANIZATION REPORT NUMBER |
|---|---|

| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) | 10. SPONSOR/MONITOR'S ACRONYM(S) |
|---|---|
| | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) |

12. DISTRIBUTION/AVAILABILITY STATEMENT
**Approved for public release; distribution unlimited**

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT **unclassified** | b. ABSTRACT **unclassified** | c. THIS PAGE **unclassified** | **Same as Report (SAR)** | **5** | |

**Standard Form 298 (Rev. 8-98)**
Prescribed by ANSI Std Z39-18

**APPROACH**

The EnVis application suite is growth–oriented. In contrast to an environment that provides one all–encompassing program for visualization, EnVis provides many related programs. The first tools implemented for the environment are the simplest both in terms of functionality and ease of use. These simple tools allow EnVis to provide command line oriented functionality to the scientists which is easy for them to learn, use, and critique. The goal of this approach it to get as much feedback as possible in early stages of development before committing resources to more time consuming efforts while still providing useful functionality to the scientists. The feedback obtained from the early efforts will help guide the future developments of more complex and elaborate systems.

The applications that may be included in the EnVis application suite are

1. evMovieLoop2D

2. evColormapEditor2D

3. evMovieLoop3D

4. evColormapEditor3D

5. evInteractive2D

6. evInteractive3D

The first applications on this list are being implemented first along with the libraries they require. Time will be taken after the initial implementation to refine and stabilize the libraries and modify the applications to best suit the needs of the scientists. As the software reaches a level of maturity and stability suitable for more complex applications, more applications will be implemented.

It is important during the early phase to identify existing or future problems and develop a strategy for dealing with them. Since one of the fundamental goals of this research is to develop durable, flexible, and powerful underlying library support, much thought must be given to its performance requirements and to the possible tasks it might be employed to perform.

The software developed for this project fits into a structure similar to the one shown below.



Code written in the development of the EnVis application suite may fall into any of the blocks shown above except for OpenInventor and OpenGL. The EnVis Toolbox provides functionality needed by all (or at least multiple) EnVis applications, but is not likely to be generally useful outside the EnVis project. EnVis applications may take advantage of the Common Object Support Toolkit (COST) and its underlying infrastructure, ercLib, as well as other, lower–level software tools – implementing necessary functionality if it does not exist.

This method of software development provides direct access to (and benefit from) the collective efforts of many developers across multiple projects. The price is participation in the collective effort and contribution of generic tools as needed. In a similar attempt to leverage other funded work, Hector [4–6] was extended to allow better utilization of the existing visualization lab in the NAVO/MSRC in making batch–mode movies.

## WORK COMPLETED

The EnVis Toolbox and Application Suite have been established. The toolbox contains class libraries for reading data from the Navy Layered Ocean Model (NLOM) version 3.4T. Using the tools provided, four of the simple applications have been developed: evMovieLoop2D, evColormapEditor2D, evMovieLoop3D, evColormapEditor3D. These applications are continuously being enhanced, but the following descriptions are currently accurate.

### evMovieLoop2D

This application is for creating a movie loop of 2D time varying data. It is command–line based, so it can be run via cron and its results viewed later. It performs no 3D operations; it simply maps scalar values to colors. Its performance has been observed to vary from several minutes per frame (for a 6 layer 1/16 degree global ocean model) to a few seconds (for 3 layer Sea of Japan model). This has uncovered the need to address enormous variation in the size of data (megabytes to terabytes) that EnVis applications may be asked to manage.

### evColormapEditor2D

evColormapEditor2D is used to affect the output of evMovieLoop2D. The colormap editor window allows the scientist to alter the colormap and see the resultant mapping immediately in the adjacent image. When the scientist gets a colormap that accentuates the features of interest, the colormap is saved for use later in movie loop creation. The images shown below are rendering of the layer thickness deviation in the top layer of a model of the Sea of Japan every 30 days. The pictures are in row–major sequence. For more details see [3].
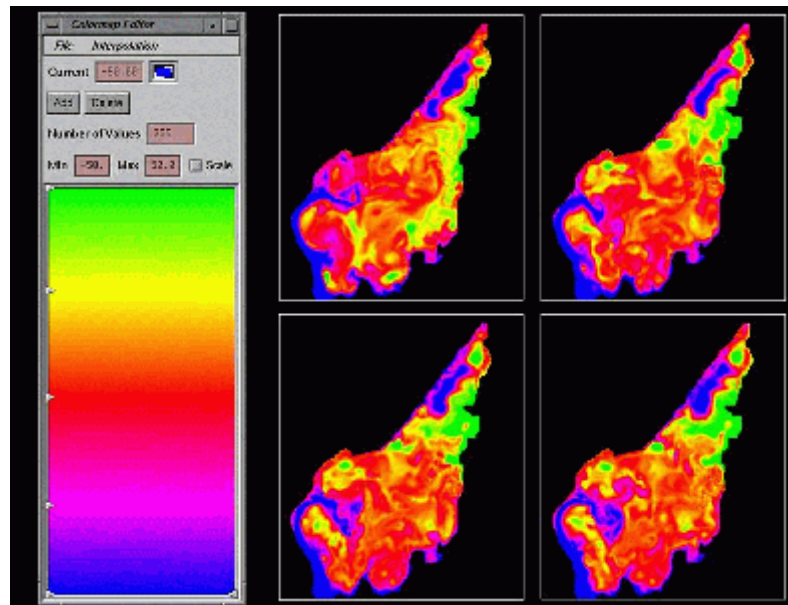


### evMovieLoop3D and evColormapEditor3D

This application is for creating a movie loop of 3D data. This may be as simple as visualizing data that change over time with fixed lighting and camera position or as complicated as a fly–through animation with time–varying light position, color, and so on. Currently only the simplest behavior is implemented. evColormapEditor3D works very similar to evColormapEditor2D. The following pictures show layer thickness deviation mapped onto a layer interface. The colormap shows how the colors are mapped, and the renderings show a sequence of time steps. The view is of a model of the Sea of Japan and the camera position is in the northeast looking southwest.
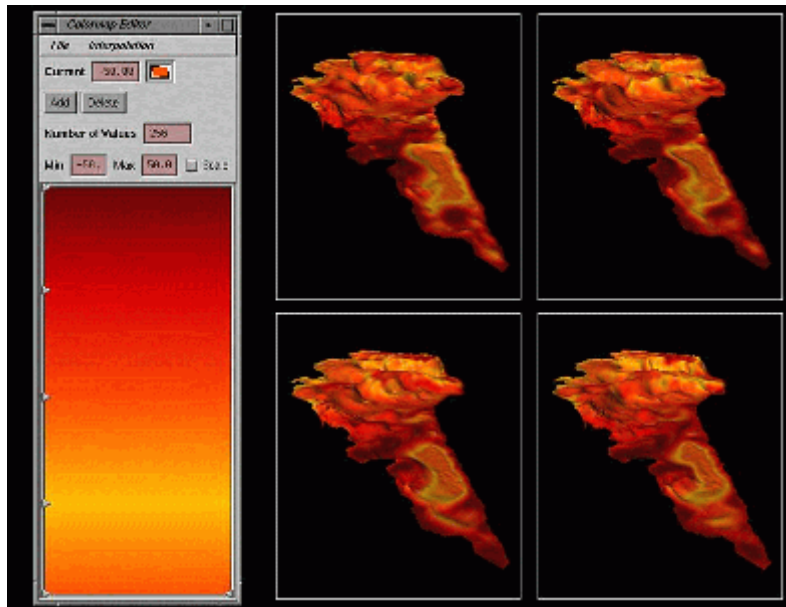
**Hector**

With regards to Hector, support from the Navy has yielded one significant technical advancement, notable advances in ease of use and in the ability to run batch, shell–script, and sequential jobs, performance enhancements, and system updates. Hector's communication library was modified to provide communication via shared memory to MPI programs transparently. That is, not only can it determine the fastest communications mechanism and switch to it automatically, but it can do so with no extra source code or user intervention. Thus Hector's communication switching is dynamic, automatic, and transparent to the user. This involved the design of the underlying architecture, as well as implementation and testing. Tests showed as much as 15% decrease in job runtime. Several additional features were developed and added to Hector to increase its ease of use and make it more suitable for actual, operational use. A Motif–based GUI is undergoing testing, and support for shell–scripted (batch) and sequential (non–parallel) jobs was added after conversations with NRL users.

## RESULTS

A functional, easier–to–use, extendible toolkit now exists for making movies. It is functional in that it lets the computational oceanographer define what is visualized and how it is rendered (contours, color–filled polygons, isosurfaces, volume rendered, etc.). It is easier to use and more extendible than the previous toolkits used by the NRL/SSC ocean modelers. With the additions made to Hector, more movies can be made in a fixed period of time and with less impact on the interactive users of the NAVO/MSRC visualization lab. The significance is that data is more often examined in the form most amenable for understanding and discovery.

## IMPACT/APPLICATIONS

This research will enable the ocean modelers to understand their results more quickly. It will allow them to visualize the direct model outputs more accurately.

## TRANSITIONS

EnVis is being used in the ocean modeling group at NRL/SSC and in the NAVO/MSRC visualization lab.

The file reader for the native NLOM 3.4T format that was developed for EnVis has been ported to ISTV. ISTV is reputed to be the only interactive visualization toolkit capable of dealing effectively

with the large NLOM files. The same reader is being integrated into DIVA, a system used in the NAVO/MSRC visualization lab to interactively visualization scattered data such as that captured from bathymetric surveys.

**RELATED PROJECTS**

Under the NSF base funding for the Engineering Research Center, we are trying to create a robust visualization system for time–varying computed model data. COST may become part of that. EnVis has influenced it.

**REFERENCES**

1. K. Gaither, R. Moorhead, S. Nations, and D. Fox, "Visualizing Ocean Circulation Models Through Virtual Environments," *IEEE Computer Graphics and Applications*, Vol. 17, No. 1, pp. 16–19, Jan.–Feb. 1997.

2. J. van der Zwaag, C. Everitt, and R. Moorhead, "COST : Common Object Support Toolkit," C++ Toolbox (in preparation).

3. http://www.erc.msstate.edu/thrusts/scivi/publications/envis/envis.html    EnVis – an Environmental Visualization Environment

4. http://www.erc.msstate.edu/thrusts/cps/hector/main/index.html    Hector home page

5. http://www.erc.msstate.edu/thrusts/cps/hector/main/onr_new.ps    More indepth discussion of Hector work done under this ONR grant.

6. http://www.erc.msstate.edu/thrusts/cps/hector/main/Report.97.8.ps    Recent technical report on Hector progress in general